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GAMING AS A TECHNIQUE OF ANALYSIS

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This is the age of the high-speed computer or, more popularly, the giant brain. Whether or not we can really breed intelligence into our high-speed digital computers, however, is not a question that will concern us here. We are interested, in fact, not in digital but rather in analog computers and, in fact, in one element of the many that go to make up an analog device. Our analog element is not a differentiator or integrator or multiplying circuit, but a human, homo sapiens we hope. That is, our concern here is not with computing machines that think, but rather with the thinker as part of a computing machine.

Now there is nothing new in solving a problem by asking an expert in the subject — or even an operations researcher — to think about the problem. This process goes back at least to the first caveman who asked his neighbor's opinion concerning the optimum tactics for tracking tigers. What does have a certain air of novelty, however, is the growing practice of imbedding a sapient human in a machine and acquiring thereby a new and different sort of machine — one whose capabilities and limitations are today understood somewhat less than perfectly.

In speaking of a "machine" we may take the word literally and understand by it a device begotten of vacuum tubes, potentiometers, and associated hardware. On the other hand, our machine may be a logical structure represented only by symbols on a piece of paper. The machines in which we are interested, however protean in form, have all of them similar functions — each is used to help solve problems connected with some decision process.

To change the terminology, our machine is a model in the sense in which that word is used in scientific theory — a model of that part of the real world with which our decision problem must deal. It is a black box into which we crank inputs and out of which are ground outputs. From these outputs we seek guidance in our decision problem.

The traditional relation of man to model is threefold. In the first place man designs the machine. That is, he decides what factors are relevant to the problem and what the interactions between these factors are to be in the machine. In particular, he decides what variables are to be inputs, what are to be outputs of the black box. In the second place, the user of the model, who may not be identical with the onlie begetter of the black box, decides the numerical values of the input variables fed into the machine. And, finally, man inspects, analyzes, interprets the results, the outputs of the model.

The human qualities of judgment and intuition are essential to all three of the activities just mentioned: the design of the model, the choice of input values, the analysis of outputs. But within the black box no meditation goes on. The machine may contain random elements — dice cup and roulette wheel may be among its components — or, on the other hand, it may be completely deterministic. But in either case the operation of the model, the passage from inputs to outputs, does not involve the attributes of judgment and intuition that we found necessary for the invention of the model.

Now we change radically the nature of the machine by imbedding a man (or several men) within it. We can, for example, insert our man into the black box by giving him a potentiometer to twist and dials from which to read the values of variables in the machine, thus setting up a feedback loop.

In a symposium organized to discuss the use and value of war game methods, it is fitting that we take a war game as an example of a model. In order that our example set no foot on terrain labeled secure, we choose it from the military activities of an earlier century. Putting behind us the temptation to discuss the war games conducted by Uncle Toby and Corporal Trim, together with the reconnaissance campaign of the Widow Wadman, we consider instead the American Kriegsspiel as played by the Volunteer Militia of Rhode Island in the years following the Civil War.

In the conventional war game of that period, the Red and Blue teams play through a military campaign in detail over a map of the theater. One or both players may follow a scenario, or each may be free to plan his tactics and attempt to carry them out under the impact of his opponent's actions. The results of the players' moves are adjudicated (after a certain amount of debate) by the umpire. For example, the umpire decides whether Red succeeded or failed in establishing a bridgehead, whether Blue was able to hold his strongpoint or was forced to withdraw. So far we appear to have only thinkers, not a machine or quantitative model. But let us turn to the American Kriegsspiel and the Volunteer Militia.

The American Kriegsspiel was developed from its Prussian counterpart, the latter having been introduced into this country about 1865. The interactions of the elements, from the effect of musketry fire to the velocity effects of a cavalry charge, were spelled out quantitatively, the rules were formalized, and the umpire's functions could be limited to the determination of random numbers for those cases in which the rules prescribed probability distributions.

Major Livermore, author of "The American Kriegsspiel,"(1) described the game as follows. "The Kriegsspiel is played upon a topographical plan, with small blocks representing the troops, which are proportional to the scale of the map .... When the oosition of the blocks indicates that the hostile troops are within sight and range of each other, they may be supposed to open fire, if the players desire it, and in this case it becomes the umpire's duty to decide the result upon the basis of experience. The rules of the game explain to him how to estimate the loss from this fire; for example, it may have been found that in similar circumstances, the number of killed and wounded has varied from ten to twenty; by throwing a common die he decides whether to assign a greater or less result to the case in view."

From this quotation it is evident that the American Kriegsspiel came closer to resembling a parlor game than did those war games in which the experienced military judgment of the umpire provided the link between the tactics chosen by Red and Blue and the results of the engagement as measured by movement and attrition of forces. In the language we used earlier, the Kriegsspiel constitutes a model, a black box in which the Red and Blue players are integral parts together with the mechanical elements as constituted by the formal rules of the game and the random number generators. The judgment and intuition of the players are used at each stage of the game to make decisions as to allocation, deployment, and operation of forces. These decisions are made under the constraints imposed by the rules, and the interactions of the various elements of the game are determined by the rules together with the random numbers generated.

This resemblance to a parlor game is essential if gaming is to be used as a technique of analysis. The game representing the problem must be easily playable and must be played numerous times by the same players so that they can develop a knowledge of the structure of the game and a feel for good strategies. A game that is to be replayed many times needs a fixed set of rules so that experience gained in one play is valid in other plays.

Our example, the American Kriegsspiel, has illustrated the more or less traditional use of the human computer as employed in a war game. This use of gaming can be extended to those non-military situations that involve elements of conflict too important to be ignored. That is, gaming may be used to study situations in which there are elements having a significant effect but which are in the control of a competitor or opponent. Such elements can be neglected only when the opponent's strategy is clearly fixed and known — a condition which sometimes obtains in the case of those simple problems which can be factored out of their context and treated as component problems, but rarely in the case of the more complex systems problems with which we are here concerned.

Having thus dropped the word "war" from war gaming, we can continue and abandon the gaming as well. That is, our man-machine computer may very well find employment in the study of problems in which no element of conflict occurs. The computation of the transportation capacity of a complex rail network may be a case in point. Other examples of a different character arise in which the responses and interactions of the humans in our man-machine model are themselves the principal object of study. The Systems Research Laboratory[(2)] at RAND has studied man-machine problems involving "the interactions between a group of ... people, associated machines and communications network working against a system criterion."

But if the characteristic of war gaming which is important for operations research has neither to do with war nor with gaming but rather with the man-machine computer, then the name "war gaming" may be something of a misnomer. Morse has used variously the labels "simplified gaming," "the gaming technique," and "simulated operational experiment" to refer to the use of the human as part of the model. As Morse says,[(3)] "Simplified gaming furnishes another means of operational experiment. Sometimes it is not sufficient to provide the random processes and then just compute the consequences; human judgment or human competition may also enter. In this case we may simplify the operation down to a specialized game (two-person or solitaire as the case may be) with the random events and other rules devised to provide a close analogue with the actual operation. By observing a reasonably intelligent person learn to play such a game we can often learn a great deal about an actual operation that is far too complicated to be analyzed by theoretical means." Morse goes on to describe the solution of antisubmarine air-search problem by this gaming technique and says "Within these few weeks we learned more about the more complicated problems of submarine search than 6 months of analytic work had taught us. Search theory could work out the simple cases well enough; the complex cases, when there were not enough planes, or when delays occurred in starting the search, had to be worked out by gaming."

What about the difficulties that attend the use of gaming. There is no need to dwell here upon those stumbling blocks that are ever with us regardless of the technique of solution. The central problem — that of the wise selection of criterion or payoff — is just as important and no easier of solution, whether gaming is used or no. The related questions of adequate measures of cost and effectiveness, of loss and profit, are still essential, and these measures are not always easy to arrive at. As in any operations research project, we must decide how much context is to be provided as a necessary background for our problem, how extensive a slice of the real world is to be modeled. If the Volunteer Militia uses the American Kriegsspiel to study new tactics proposed for the horse artillery, then it may be that little additional context is needed. A game may be designed with few elements other than those directly and obviously concerned with the horse artillery. If, on the other hand, the game is called upon for assistance in deciding proper budget for the horse artillery, then far more context is required. This is a system problem rather than a component problem; it is a problem that can not be detached from its natural context, that can not be factored out and treated separately from all the other military and economic factors that are entangled with it.

Another vexing problem, but again one not unique to gaming, is that of the proper amount of fine structure to be included in the model. In our attempt to be realistic, how much detail must be preserved, how much can be sloughed off or aggregated. The player of American Kriegsspiel can even dispatch a cavalry charge and take into account the aversion of the horses to tread upon prone infantrymen.

These problems of suitable criterion, adequate measures of cost, proper amount of context, necessary level of detail are important problems; they deserve all the study and need all the help the ORSA can give. But they are not unique to gaming; on the contrary, the analyst must contend with them however he may choose to make his analysis. On the other hand, gaming does aggravate some of these knotty points and may even introduce a few of its own. Consider the matter of evaluating the sensitivity of the results of an anlysis to parameter values, to model structure, to payoff. In the simplest of models it may be possible to make sensitivity tests analytically. More complex models may demand extensive numerical computation, particularly if random elements are present. The sensitivity problem becomes even harder to handle if human decision links are used in the model, that is, if the analysis employs gaming. A partial solution lies in the direction of making the game easily playable and hence repeatable.

A second apparent drawback to gaming is that it discards the possibility of analytical optimization. The theory of games has developed a considerable body of clarifying ideas and a technique which can analyze simple economic and tactical questions. In particular, the theory of games may furnish solutions to some factorable component problems and these suboptimizations may be built into our machine. However, the theoretical techniques now available are not even remotely capable of dealing with complex systems problems.

The last difficulty attendant upon gaming to be mentioned here is that playing a game may be too easy and too attractive. That is, the temptation is great to devote too much effort to play, too little effort to good design of play and of the game itself to the end that desired results may be achieved. An allied point is that of achieving good play, of insuring, for example, that a player's decision is made in accordance with the specified criterion or payoff of the game and not dictated merely by the quirks and crotchets of the individual human player, bedeviled as he is by the accumulated prejudices of a lifetime. However, this is less of a stumbling block for gaming than might first be supposed. The human decision link in our machine is not free but is rather bound by all the constraints of the machine, constraints that express the structure of the model and that have been arrived at by combining the knowledge and experience of many experts. So, while irrational play may be present in either the gaming solution of a problem or in a solution arrived at by a round-table discussion among experts, the gaming technique does have some built-in safeguards.

We have characterized gaming as the use of a model containing a human decision link. Now this man inside the machine is not a hypothetical Maxwell's demon with that character's attribute of infallibility. On the contrary, we have a real and therefore fallible human. What can we possibly gain by adding to our machine an element whose unreliability and unpredictableness exceed that of our electronic gear. In other words, why game?

The construction of a game involves judgment at every turn: in the scope of the game, the level of detail, the content of the rules, the adequacy of its representation of reality, the opinions of players as to what are good strategies. Why not just answer the questions the game is supposed to analyze by referring to an expert in the area of the given problem? What does the game do that an expert cannot do?

The expert, of course, is not the only alternative to the use of the man-machine computer in studying complex problems. Instead of dispensing with the machine we can dispense instead with the man. The former choice corresponds to the use of the expert — or a committee of experts. The latter course is the usual scientific model-building of the operations researcher. This modeling of the real world by a machine has been a potent tool in the study of component problems. For the more complex systems problems that cannot be factored out of their context, however, analysis by a model, by a pure machine, is usually feasible only if the real world is ruthlessly simplified with the accompanying sacrifice of elements that may be essential.

A game pools the knowledge of numerous experts. The more complex a problem is, the less the likelihood that a person can be found who is expert in all its facets. And even if such a person could be found, he would himself have to integrate in his mind all this special knowledge into one coherent structure and analyze that structure.

Having just disposed of the catholic expert, we must now admit that we have been too glib — that we can not really dispense with him completely, although we can make his job a finite and feasible one. For recall that the man within the machine is not the only human involved in the game. As we saw earlier in talking of scientific model building and using, man designs the model, chooses input values, and analyzes the results. The designing of a model, the writing of a set of rules for a game is a major project. Decisions must be made as to the amount of context to be included. Those aspects which are retained in the game must be simplified and combined into easily manipulable factors in the interest of having a playable and understandable game. Planning factors must be compiled, the interactions of various factors spelled out, and side studies made to fill in areas where rules are necessary but knowledge lacking.

In the language of our computer analogy, the great advantage of the man operating within the machine is that he is not free. He is bound by the constraints of the model, constraints that have been built into the machine to represent the results of component studies on various pieces of the problem, and the pooling of experience and judgment concerning portions of the problem.

Gaming, like all model building, has another paramount advantage over unbuttoned judgment — it forces the explicit recognition and statement of assumptions. Intuition and instinct are indispensable to the operations researcher; abandon them and he abandons the power of creative thought. But however important are suggestion and supposition, speculation and surmise, it is equally important that these things be clearly recognized and labeled.

A virtue of gaming that is sometimes overlooked by those seeking grander goals — the solution of allocation problems or the study of the military worth concept, for example — is its unparalleled advantages in training and educational programs.

A game can easily be made fascinating enough to put over the dullest facts. To sit down and play through a game is to be convinced as by no argument, however persuasively presented.

But to return to our discussion of the use of man-machine as opposed to machine alone or man alone. For a very complex problem it certainly is necessary to combine the knowledge and experience of many experts. It is a plausible assumption that a carefully organized combination of their knowledge into a single self-consistent whole would provide a much firmer basis for decisions than, say, a round-table discussion among experts. Of course, it is a great deal more trouble too, but we face many problems that justify the effort.

A game is an endeavor to put down in writing a basic structure which must necessarily be a part of any intelligent consideration of any nonfactorable problem. People can then see it and study it and debate it, and over a period of time arrive at some sort of general agreement about it. Even when that has been accomplished, gaming is admittedly an inexact analytical tool beside the methods that chemists and physicists use, for example. But it is a wide step beyond armchair judgment in the sense that it provides an operational and roughly verifiable (repeatable by other persons) technique for dealing with problems not otherwise amenable to quantitative analysis.

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